Integrated Studies of Oceanographic Processes and Shallow Water Acoustics in the South China Sea: Custom Climatology and Mid-Shelf Field Work

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LONG-TERM GOALS

Our long-term goal is to study oceanographic processes on the continental shelves surrounding Taiwan and their impact on sound propagation in shallow water.

OBJECTIVES

The objectives for this project were to construct a climatology for the South China Sea and use previously developed techniques to identify geographical regions with enhanced oceanographic contributions to uncertainty in sonar system performance, and to analyze data collected during the VANS/WISE Shallow Water studies in April, 2005. Both objectives were undertaken in close collaboration with scientists at National Taiwan University.

APPROACH

We have used the Taiwanese hydrographic data base to construct two separate climatologies for the South China Sea and continental shelves surrounding Taiwan. We used a climatology toolbox developed by C. Linder during the Capturing Uncertainty DRI in order to obtain both planview fields of temperature, salinity, density, and sound speed as well as cross-shelf fields in four continental shelf regions surrounding Taiwan. The regions are Taiwan Strait, the northern South China Sea, the shelf east of Taiwan, the the East China Sea northeast of Taiwan.

The second climatology covers the deep basin of the South China Sea and Luzon Strait. This work is being done by Jen-Hua Tai, a graduate student from National Taiwan University who is presently a guest student at WHOI. He is looking at seasonal variations in the position of the Kuroshio as well as the vertical structure of the Kuroshio.

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We are also analyzing the shallow water field data collected during April, 2005. We are looking at the effect of nonlinear internal waves of elevation on acoustic propagation.

WORK COMPLETED

We have completed the climatology of the continental shelves around Taiwan. We have produced both planview maps and cross-shelf sections of temperature, salinity, density, and soundspeed around Taiwan. In order to cover more sparsely covered regions in the deep basin, we needed to use larger areas for weighting in deep water relative to the continental shelf. A technical report has been completed which includes all the climatological fields (Linder et al., 2006).

The data collected during the April, 2005 experiment has all been processed and calibrated. We are presently in the process of analyzing the data in terms of timing of elevation waves of large amplitude, structure of internal tidal bores, and structure of soundspeed field for acoustic modeling for use in propagation studies.

We completed a study on interannual variation of the Kuroshio Intrusion into the South China Sea (Caruso et al., 2006) as well as another study on quantifying uncertainty in ocean modeling (Lermusieax et al., 2006).

RESULTS

From the climatology, we have mapped the temperature and sound speed structure into a cross-shelf coordinate with an origin at the shelfbreak. For spring in the East China Sea, the mean sound speed appears in Figure 1. We have found that there is consistently higher standard deviations of temperature and sound speed near the shelfbreak (Figure 2). This is presumably due to the meandering and variability of the Kuroshio in this region. In the depth range of 80-100 m, there is an interesting peak in the standard deviation of sound speed to the northeast of Taiwan (Figure 3). This may be associated with Kuroshio flows onto the continental shelf. There are a number of canyons in this region which may serve as conduits onto the shelf.

From the field work in April, 2005, data from both the low-cost Tidbit moorings as well as the Scanfish data suggest that there are large amplitude elevation waves propagating onto the continental shelf. Examination of the temperature time series, with sensors spaced at 5 m intervals in the vertical in each of four moorings, suggest that there are internal waves of amplitude 30 m which propagate from the 90 m to 70 m isobath. The largest amplitude waves appear at roughly a diurnal period (Figure 4). Data from the Scanfish suggests that there are regions of significant overturning (density inversions) on vertical scales of up to 20 m. We have also identified isolated boluses of cold water propagating onshore, which verifies the idealized modeling study of Venayagamoorthy and Fringer (2006).

The impact of the internal waves of elevation has been studied. Transmission Loss (TL) vs. time measured at two nearly orthogonal bearings ($82.5^{o} \pm 7.5^{o}$ (red) and $337.5^{o} \pm 7.5^{o}$ (blue)) is shown in the top half of Figure 5. During the time period shown, internal wave activity was observed, with a propagation vector (measured via radar) of 338^{o}. The red curve shows TL vs. time in a case where the acoustic propagation paths are normal to those of the internal waves, while the blue curve shows the TL in a case where the acoustic propagation paths are parallel to those of the internal waves. There is a consistent difference of about 2- 5 dB between these two curves during the period between 11:00 and

14:00 and a 5 dB peak occurs near 12:30. It is hypothesized that the increased TL measured at 337.5 º is the result of the orientation of its acoustic propagation vector being parallel to the internal wave propagation vector. In this situation, strong gradients cause the acoustic wave to spiral (i.e. refracting in both the horizontal and vertical planes) with increased transmission. Evidence of internal wave activity can be seen in the strong temperature gradients observed in the temperature vs. time curve shown in the bottom half of Figure 5. Similar observations occurred at to the thermistor string data shown in Figure 6, which also exhibits strong gradients during the time period where large differences in TL were measured.

We have also completed our study of the inter-annual variability of the Kuroshio Intrusion (Caruso et al., 2006). We found that there are two forms of intrusion. More typically, the intrusion is in the central region of Luzon Strait and results in an anti-cyclonic circulation in the northeastern South China Sea. However, in some years, the intrusion is located in the northern portion of Luzon Strait and a cyclonic intrusion results.

IMPACT/APPLICATIONS

We are using our results to better understand acoustic propagation and sonar performance prediction using methods we have previously developed in the Capturing Uncertainty in the Tactical Environment DRI (Linder et al., 2005). We have used the climatology in a number of different ways, including planning for the field work in the South China Sea in the NLIWI program. We have also been in contact with modelers from the NLIWI program to study internal wave shoaling and dissipation.

We will also be using our field data to apply the Probabilistic Prediction of Detection (PPD) methodology developed by P. Abbot and I. Dyer to the South China Sea.

TRANSITIONS

We are presently in the process of transitioning our custom climatology software to the Naval Oceanographic Office in Bay St. Louis, MS. We have had several meetings with this group as part of the Rapid Transition Program between ONR and the Naval Oceanographic Office. P. Abbot has also been active in transitioning the Probabilistic Prediction of Detection methodology to the Naval Oceanographic Office.

RELATED PROJECTS

The work on this project also relates to our work on AWACS (Advanced Wide Aperture Cluster Surveillance) in which we are using REMUS Autonomous Underwater Vehicles to study acoustic surveillance techniques using multiple vehicles. We are also interacting with a number of Investigators in the NLIWI and Shallow Water Acoustics 06 program. Key collaborators include L. St. Laurent of Florida State University, who made very interesting cross-shelf and time series profiles of dissipation during our cruise; Ching-Sang Chiu of the Naval Post-Graduate School, who measured acoustic propagation, and P. Abbot, who is continuing his work on estimating uncertainty in sonar system performance parameters.

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PATENTS

None

HONORS/AWARDS/PRIZES

None

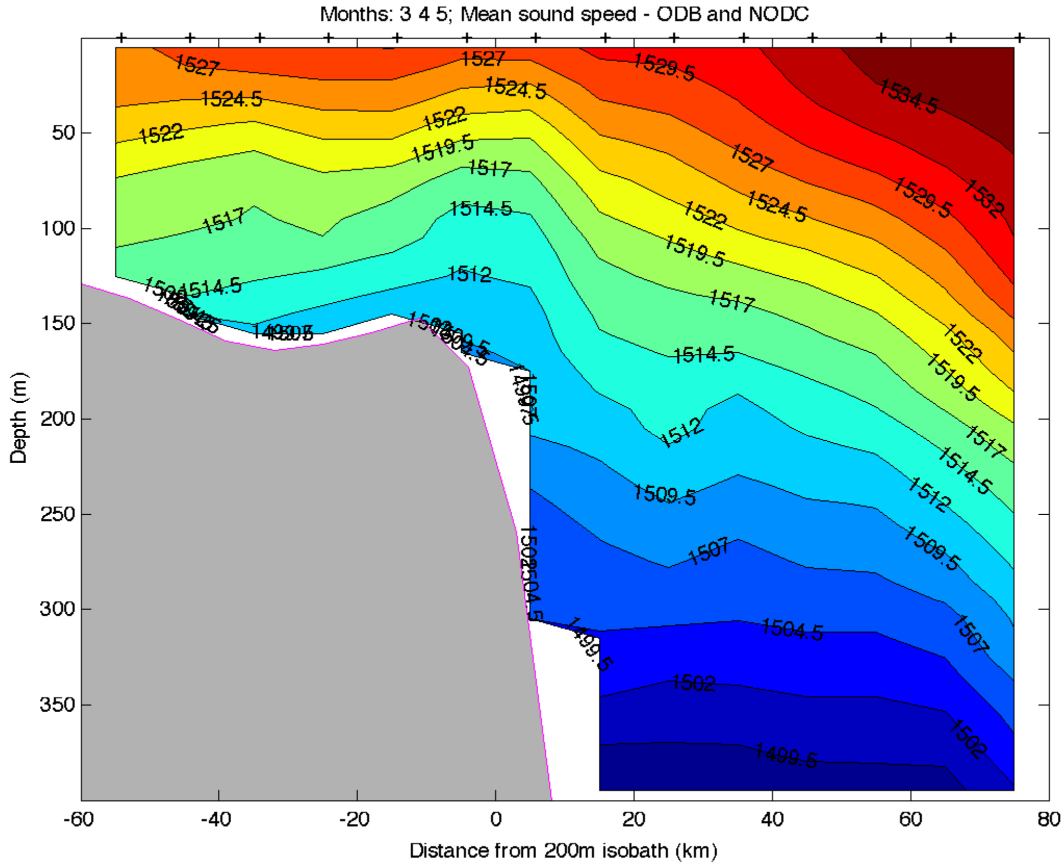

Figure 1. Mean sound speed field for the continental shelf northeast of Taiwan in the East China Sea. This is for spring conditions. Note the low sound speeds over the shelf near the bottom as well as the frontal structure offshore associated with the Kuroshio.

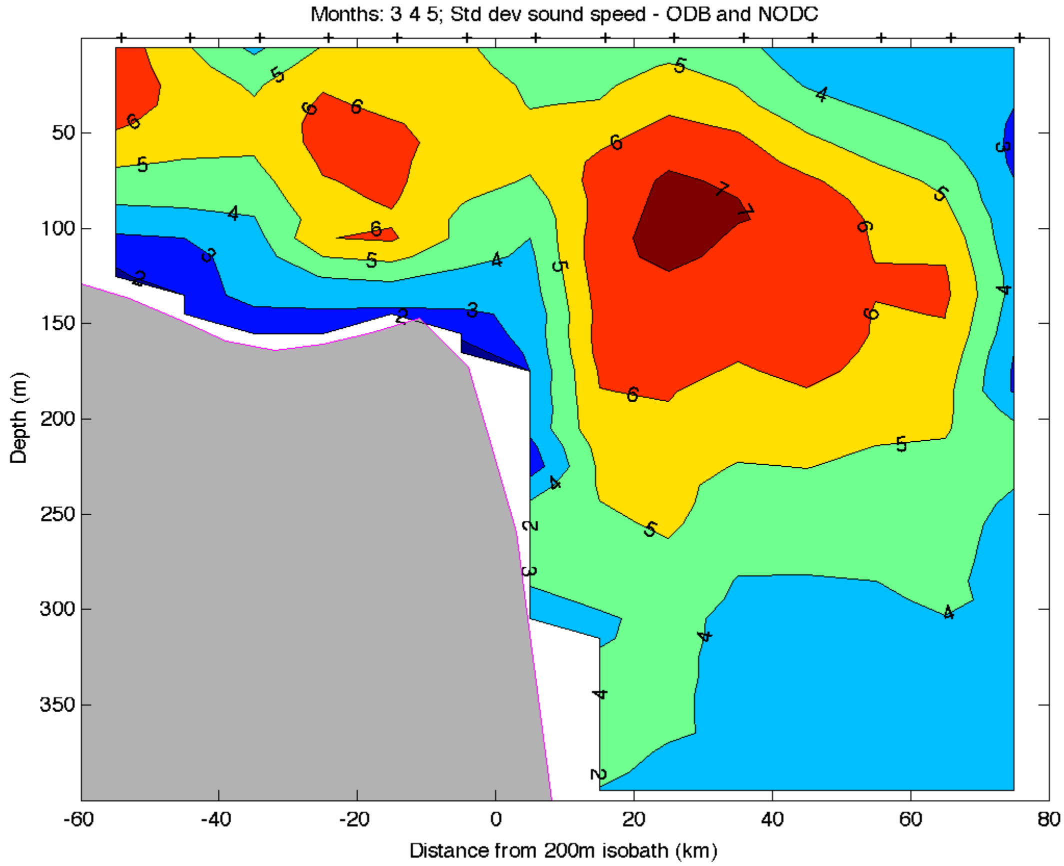

Figure 2. The standard deviation of the sound speed over the outer shelf and slope in the East China Sea northeast of Taiwan. The large peak at x=20 km is presumably due to motions of the Kuroshio. Note the secondary maximum at x=-20 km over the shelf. Note the maxima appear in the depth range of 50-100 m.

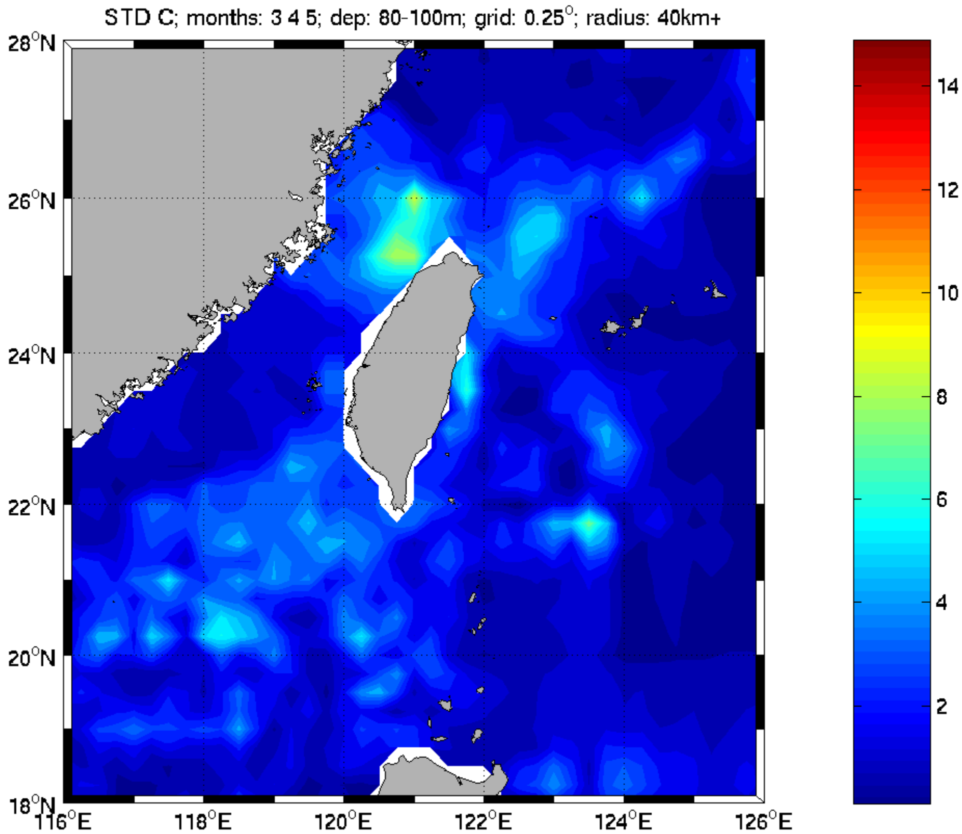

Figure 3. A plan view of the standard deviation of temperature between 80-100 m depth during the spring. Note that there are two local maxima north of Taiwan, one in the northern portion of Taiwan Strait and a second along the shelfbreak northeast of Taiwan.

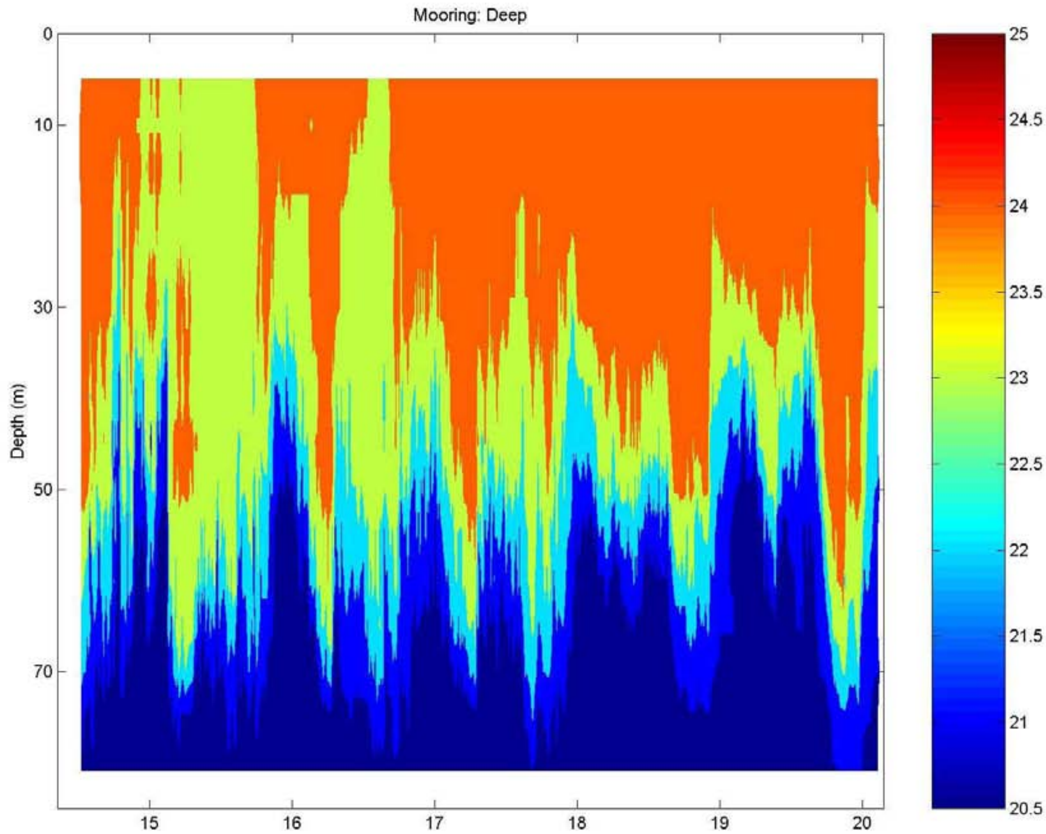

Figure 4. A time series of temperature from April 14-20, 2005, showing large amplitude elevation waves over the continental shelf. The largest waves have an amplitude of 30 m.

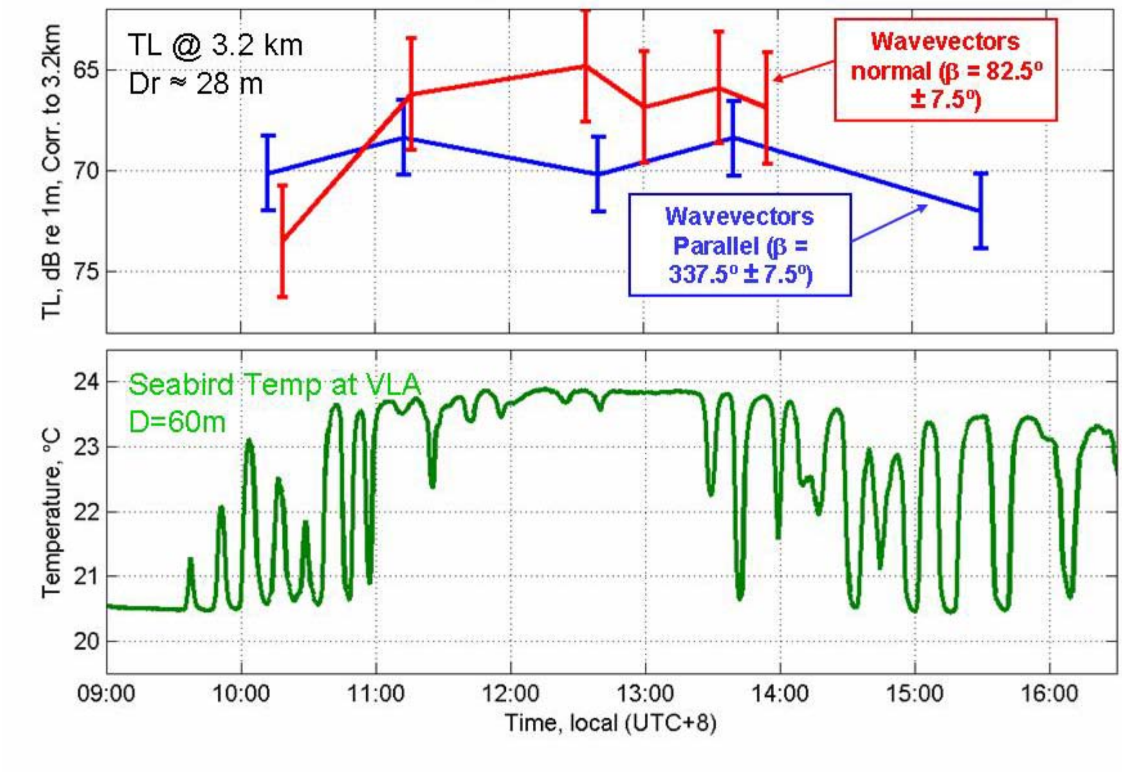

Figure 5 (Top) Transmission loss at 3.2 km Range versus time at two orthogonal bearings during the passage of internal waves. (Bottom) Temperature versus time at the receiver, the Vertical Line Array.

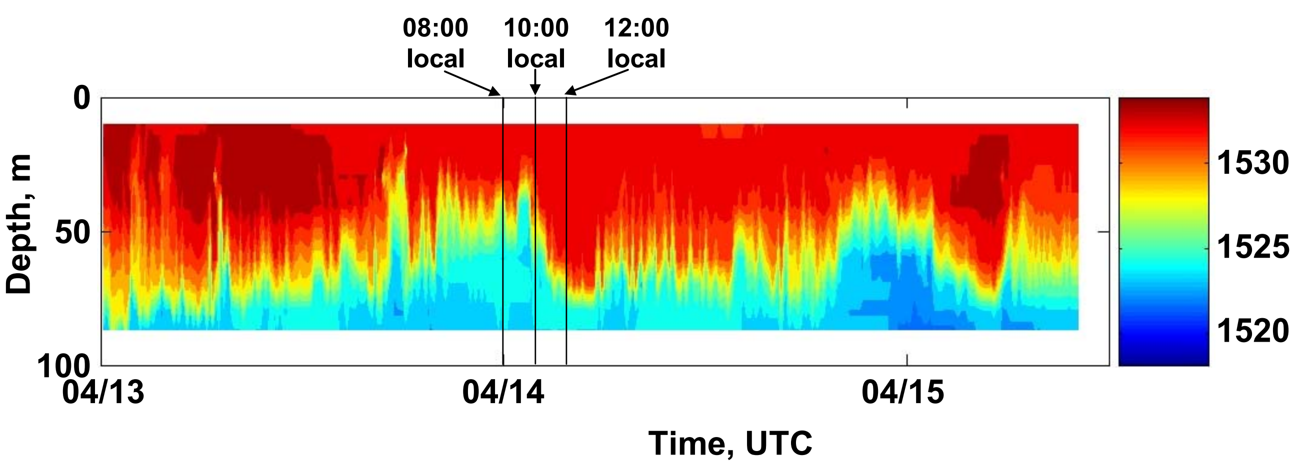

Figure 6. Thermistor string at the Vertical Line array showing the passage of internal waves. The temperature from the thermistors has been converted to sound speed.